

METHOD FOR FILTERING A MOBILE RADIOTELEPHONE SIGNAL
AND CORRESPONDING MOBILE RADIOTELEPHONE RECEIVER
[VERFAHREN ZUM FILTERN EINES MOBILFUNKSIGNALS UND
ENTSPRECHENDER MOBILFUNKEMPFÄNGER]

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VERFAHREN ZUM FILTERN EINES VERFAHREN ZUM FILTERN EINES
MOBILFUNKSIGNALS UND ENTSPRECHENDER MOBILFUNKEMPFÄNGER

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The present invention relates to a method for filtering a mobile radio signal that has been received, according to the preamble of Claim 1 and a corresponding mobile radio receiver according to the preamble of Claim 20.

7 Mobile radio systems are generally designed so that they are cellular in order to be able to cover even larger spatial areas with a limited frequency band width. As Fig. 2 shows, this type of cellular mobile radio system comprises several radio cells 17, whereby each radio cell is assigned its own mobile radio channel. In a radio cell, the radio cells adjacent to the mobile radio channels are not used. However, since the radio field attenuation is limited in this type of mobile radio system, noise or interferences are caused in each radio cell 17, especially due to the mobile radio channels of the immediately adjacent radio cells. This concerns mainly the limit area between two adjacent radio cells 17. Interferences of this type are designated as adjacent channel interferences. The adjacent channel noise immunity, i.e., the relationship between the signal power and the interference power of adjacent channels

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significantly influences the spectral efficiency of a mobile radio system.

In mobile radio receivers, the mobile radio signal received is usually sent to a receiving filter for filtering. As Fig. 3 shows, the effectiveness of this type of receive filter depends mainly on the spectral position and the power density $S(f)$ of the adjacent channel interferences. This means that in the example shown in Fig. 3, even after the receive filtering, adjacent channel interferences occur both on the lower end area 18 marked in black and on the upper end area 19 marked with shading, of the frequency spectrum of mobile radio channel no. 2 because of the mobile radio channels no. 1 and/or no. 3 of the adjacent radio cells. While the adjacent channel interferences that still remain in the lower end area 18 are negligible, the remaining adjacent channel interferences in the upper end area 19 are still relatively strong. In contrast to Fig. 3, real receive filters essentially do not have infinite edge steepness, which means that the interfering influence of the adjacent channels is further increased.

However, receive filters can not be sized in such a way that, on one hand, they suppress strong adjacent channel interferences and thus improve the bit error rate and, on the other, do not have a negative effect on the bit error rate if adjacent channel interferences do not occur. A receive filter that is optimum for both cases can not be dimensioned.

Therefore the present invention is based on the task of providing a method for filtering a mobile radio signal and a

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corresponding mobile radio receiver, whereby the above mentioned problems can be eliminated and, in particular, it is possible to have adjacent channel interferences filtered out without increasing the bit error rate if adjacent channel interferences do not occur.

According to the present invention, this task is solved by a method with the characteristics of Claim 1 and/or a mobile radio receiver with the characteristics of Claim 20. The subclaims each define preferred and advantageous embodiments of the present invention.

According to the invention, the mobile radio signal received is first analyzed for the presence of adjacent channel interference, whereby a filtering of the mobile radio signal only takes place if the analysis has shown that adjacent channel interferences are actually present. Because of this selective and/or adaptive filtering of the

mobile radio signal received, unnecessary filtering of a mobile radio signal without adjacent channel interference is avoided.

The analysis and the selective filtering of the receive signal can be carried out with the help of an appropriate algorithm, the complexity of which is low enough that it can be

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executed without problems with the digital signal processor that is present in current mobile telephones anyway.

In mobile radio receivers, which are operated, e.g., according to the GSM mobile radio standard, complex scanning values are digitized in bursts for the subsequent signal processing. The present invention thus suggests that the receive signal be analyzed, preferably in bursts, before it is supplied to the equalizer in the mobile radio receiver, whereby in each case the frequency spectrum of the analyzed burst is evaluated. If during this analysis interference is detected due to at least one adjacent channel interference, a corresponding filtering is carried out while there is no filtering if no adjacent channel interference is found.

Parameters can be set for the decision criterion for detection of adjacent channel interferences, which clearly improves the error bit rates when there is adjacent channel interference, in comparison to signal processing without the use of the present invention and at the same time, there is no negative effect if there is no adjacent channel interference, e.g. with so-called same channel or random noise interferences.

The invention will be explained in more detail below using preferred embodiments with reference to the attached drawing.

Fig. 1 shows a simplified structure of a mobile radio

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system

consisting of a sender and a receiver, whereby the present invention is used for the receiver.

Fig. 2 shows an illustration to explain the structure of cellular mobile radio networks and

Fig. 3 shows an illustration to explain adjacent channel interferences.

Fig. 1 shows, schematically, the structure of a mobile radio sender 1 and of a mobile radio receiver 8. Sender 1 comprises a speech encoder 2 that converts an analog speech signal into a digital bit stream and supplies it to a channel encoder 3. Depending on the specific channel coding method, the channel encoder adds, to the actual effective bits, additional redundant bits or information which can be evaluated on the receive side for detecting transmission errors. The initial data of the channel encoder 3 are supplied to an interleaver 4, which sorts them temporally in order to produce a quasi-memoryless channel. A burst assembler 5 is connected in circuit after the interleaver 4, which embeds the data to be transferred into a frame structure and supplies it to a modulator 6 in the form of bursts, i.e., physical channels. Modulator 6 modulates the information to be transferred to a carrier signal, which is finally transmitted by a high frequency sending part 7 over a

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high frequency channel to mobile radio receiver 8.

Receiver 8 has a corresponding high frequency receiving part 9, a demodulator 10, a burst deassembler 13, a deinterleaver 14, a channel decoder 15 and a speech decoder 16, each of which reverses the functions of the previously explained components of sender 1. In addition, according to Fig. 1 an equalizer is provided between demodulator 10 and burst deassembler 13, with a unit 11 connected

in circuit before it for spectral analysis of the receive signal and for selective and/or adaptive receive filtering.

In the following, more details will be given on the function of this unit 11.

Unit 11 has the task of analyzing the bursts received by receiver 9 and evaluating them for the presence of adjacent channel interference depending on the results of the analysis. If adjacent channel interference is determined in the frequency spectrum of the analyzed burst, its scanning values, which are generally in a complex digital form coming from the demodulator 10, are filtered in order to eliminate the adjacent channel interferences, while if no adjacent channel interference is determined, the burst scanning values will be supplied, unchanged, to the downstream equalizer 12 and the subsequent

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components for further signal processing. The function of unit 11 is preferably carried out, according to an appropriate algorithm, by the digital signal processor that is provided in the mobile telephones anyway.

The algorithm to be carried out by unit 11 can be implemented in different ways with different computing effort. In the following, four embodiment examples of the present invention will be explained.

According to a first embodiment example, for detection of adjacent channel interference, it is suggested that first the energy is determined in a narrow frequency band at the lower end (e.g., area 18 shown in Fig. 3) and at the upper end (e.g., the area 19 shown in Fig. 3) of the frequency spectrum of the burst to be analyzed. Then the energies thus determined at the lower and upper end of the burst spectrum are compared to each other, whereby a ratio formation is especially recommended for this, since because of this a decision is possible that is independent of the average burst energy. Without adjacent channel interference, the ratio thus formed is ideally equal to 1, so that adjacent channel interference can be recognized in that the ratio value is compared to a tolerance range lying above the value 1, i.e., with a lower and an upper limit. If the ratio value lies outside

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this tolerance range, a decision is made that adjacent channel interference is present.

If adjacent channel interference was detected in this way, a filtering of the original received scanning values of the corresponding burst is carried out in order to eliminate the adjacent channel interference(s). This filtering is preferably only carried out for that side of the burst spectrum that has the higher interference energy. For this purpose, the filtering can be designed in the form of a non-recursive digital FIR low pass filtering (finite impulse response) with linear phase response, whereby the frequency response of the FIR filter used for this is only asymmetrical to the ordinate only on the side with interference, i.e., to the center of the burst spectrum, and for this reason has complex filter coefficients. However, there can be a filtering other than FIR filtering, especially, e.g., an IIR filtering with the somewhat linear phase response. After filtering, the filtered scanning values will be transmitted to the equalizer 12 for further processing.

As has been described above, according to this first embodiment, the determination of energy at the lower and the upper end of the burst spectrum is necessary. For this purpose, the spectrum of the complex scanning values of the burst can be shifted by a value $+\Delta f$ and/or a value $-\Delta f$ and the shifted burst spectrum is then low pass filtered. In this process, preferably a recursive digital IIR low pass filtering (infinite impulse response) is used, since in this case the

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effort for implementation is lower in comparison to an FIR filtering and in addition, the non-linear phase response of the IIR low pass filtering does not interfere during detection.

Shifting of the burst spectrum can be carried out in correlation with the modulation set of the Fourier transform, in each case by multiplication of the burst scanning values by a corresponding shift sequence. This shift sequence has different lengths, depending on the desired frequency shift. In this process a frequency shift of $\Delta f = 101 \text{ kHz}$ has proven to be advantageous, since at this shift a detection of adjacent channel interferences is already possible and the shift sequence consists of only eight (in some cases complex) values. However, naturally other frequency shifts are also possible.

Instead of the double shift of the burst spectrum with subsequent low pass filtering, even without shift, a filtering of the burst spectrum can be carried out with two bandpass filters, the pass-band ranges of which lie in the area of the lower and/or upper end of the burst spectrum.

According to a second preferred embodiment example of the present invention, a modification of the first embodiment example described above is provided in such a way that a symmetrical FIR filter is used to suppress adjacent channel interferences. In this case, after determination of adjacent

channel interferences, independently of the side of the burst spectrum having interference, not only the part of the burst spectrum with interference, but also the part on the other side of the burst spectrum that may be free of interference is filtered. The procedure has the advantage that, because of the use of

a symmetrical filter, this has real filter coefficients and because

of that the computing effort can be approximately halved.

In correlation with the third embodiment example of the present invention, an alternative procedure is suggested for determining and filtering adjacent channel interferences, which differs from the two previous embodiment examples.

According to this third embodiment example, first the total energy E_{orig} of the burst spectrum is determined. Then a symmetrical filtering is carried out, i.e. the burst is first handled as if the adjacent channel interferences were present. After that there is an evaluation of whether this filtering action was actually justified or not. For this reason, energy E_{filt} of the filtered burst spectrum and/or of the corresponding scanning values is determined and compared to the energy E_{orig} of the unfiltered original burst spectrum, whereby to do this, the calculation of the following expression especially makes sense:

$$\frac{E_{\text{orig}} - E_{\text{filt}}}{E_{\text{orig}}}$$

The expression determined in this way is compared to a limit value, for which parameters can be set, whereby a decision can be made on the presence of adjacent channel interference if this expression is higher than the limit value, i.e., if E_{orig} is clearly higher than E_{filt} .

If adjacent channel interferences were determined in this way, the filtering that was already carried out was justified and the filtered scanning values will be sent to the equalizer 12 shown in Fig. 1 for further processing. On the other hand, if no adjacent channel interference was found as a result of calculating the expression above, the filtering carried out was not justified and the original unfiltered scanning values will be sent to equalizer 12 for further processing.

The third embodiment example describe above has the advantage that the frequency shift routines and the IIR filtering required in the first two embodiment examples are

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eliminated and thus the effort for interference signal suppression can be further reduced.

According to a fourth embodiment example of the present invention, the third embodiment example can be modified such that the process steps are no longer applied to an entire burst, but are used separately for each burst half, i.e., the calculations described above will be carried out separately for the two halves of the burst to be analyzed. So, for example, an interference signal that only occurs within a half burst duration can be better detected and eliminated. In addition, with the procedure, it is possible to dispense with unnecessary filtering of the second burst half if none is needed.

Patent Claims

1. Method for filtering a mobile radio signal, whereby a mobile radio signal received by way of a mobile radio channel is filtered before its further processing, characterized in that the mobile radio signal received is analyzed for the presence of adjacent channel interference and that, if adjacent channel interference is found in the mobile radio signal received, this is selectively filtered before further processing to suppress the adjacent channel interference.

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2. Method according to Claim 1,
whereby the received mobile radio signal comprises scanning
values combined into bursts,
characterized in that
for analysis of the mobile radio signal, it is analyzed in
bursts, whereby in each case the frequency spectrum of the
individual burst is analyzed.

3. Method according to Claim 2,
characterized in that
during the analysis of a burst of the received mobile radio
signals, adjacent channel interferences are detected in that the
energy contained at the upper end (19) of the burst frequency
spectrum and the energy contained at the lower end (18) of the
burst frequency spectrum are determined and compared to each
other,
whereby if there is a defined deviation between these energies
determined in this way, a decision is made that adjacent channel
interferences are present.

4. Method according to Claim 3,
characterized in that
the ratio is formed between the energies determined in this way
at the upper and lower ends of the burst frequency spectrum and

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that a decision is made that adjacent channel interferences are present if the ratio value lies outside of a specific tolerance range around the value 1.

5. Method according to Claim 3 or 4, characterized in that upon determination of adjacent channel interferences, the received scanning values of the analyzed burst are subjected to an FIR low pass filtering and then output for further processing.

6. Method according to Claim 5 and Claim 3 or 4, characterized in that because of the FIR low pass filtering, frequency percentages are filtered out on that end of the burst frequency spectrum for which higher energy was determined.

7. Method according to one of Claims 2-4, characterized in that if adjacent channel interferences are determined, the received scanning values of the analyzed burst are subjected to a symmetrical FIR low pass filtering and then output for further processing.

8. Method according to one of Claims 3-7, characterized in that for determining the energy contained at the upper end (19)

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and/or at the lower end (18) of the burst frequency spectrum, the burst frequency spectrum is shifted by an amount of $+\Delta f$ or $-\Delta f$ and low pass filtered.

9. Method according to claim 8, characterized in that

$+\Delta f = 101 \text{ kHz}$.

10. Method according to Claim 8 or 9, characterized in that the burst frequency spectrum is shifted by multiplying the received burst scanning values by a shift sequence.

11. Method according to Claims 9 and 10 characterized in that the shift sequence comprises eight values.

12. Method according to one of Claims 8-11, characterized in that the frequency spectrum shifted by $+\Delta f$ or $-\Delta f$ of the analyzed burst for determining the energy contained at the upper end (19) of the burst frequency spectrum or at the lower end (18) of the burst frequency spectrum is subjected to an IIR low pass filtering.

13. Method according to one of Claims 3-7, characterized in that

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for determining the energy contained at the upper end (19) of the burst frequency spectrum or at the lower end (18) of the burst frequency spectrum, the burst frequency spectrum is subjected to a first bandpass filtering with a pass-band range lying at the upper end (19) of the burst frequency spectrum and a second bandpass filtering with a pass-band range lying at the upper end of the burst frequency spectrum.

14. Method according to Claim 1 or 2, characterized in that during the analysis of a burst of the received mobile radio signal, adjacent channel interferences are determined in that the energy of the frequency spectrum of the analyzed burst is determined, the received scanning values of the burst are filtered for elimination of possible adjacent channel interferences and the energy of the frequency spectrum of the filtered burst is determined and compared to the energy of the frequency spectrum of the unfiltered burst, whereby a decision is made that adjacent channel interferences are present if the energy of the frequency spectrum of the unfiltered burst deviates from the energy of the frequency spectrum of the filtered burst by more than a specified tolerance value.

15. Method according to Claim 14, characterized in that during filtering of the burst to be analyzed, an FIR filtering is carried out.

16. Method according to Claim 14 or 15, characterized in that upon recognition of the presence of adjacent channel interferences, the filtered scanning values are output for further processing, while upon recognition of the absence of adjacent channel interferences, the unfiltered scanning values are output for further processing.

17. Method according to one of Claims 14-16, characterized in that for comparison of the energy of the frequency spectrum of the unfiltered burst to that of the frequency spectrum of the filtered burst, the ratio $(E_{\text{orig}} - E_{\text{filt}}) / E_{\text{orig}}$ is calculated and compared to the specified tolerance value, whereby E_{orig} corresponds to the energy of the frequency spectrum of the unfiltered burst and E_{filt} corresponds to the energy of the frequency spectrum of the filtered burst.

18. Method according to one of Claims 14-17, characterized in that the energies are determined for both the entire unfiltered and

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the entire filtered burst, whereby during the filtering of the burst,

it is subjected to a symmetrical filtering.

19. Method according to one of Claims 14-17, characterized in that the individual process steps are carried out separately for each burst half of the analyzed burst.

20. Mobile radio receiver, with a receiving part (9) for receiving a mobile radio signal transmitted over a mobile radio channel, with a demodulator (10) for demodulating the received mobile radio signals, and with an equalizer (12) for equalizing the demodulated mobile radio signal before it is further processed in the mobile radio receiver, characterized in that, analysis means (11) for analyzing the demodulated mobile radio signal with respect to the presence of adjacent channel interferences are provided, which are designed in such a way that upon determination of adjacent channel interferences in the demodulated mobile radio signal, they selectively filter it for suppression of the adjacent channel interferences and send it to the equalizer (12).

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21. Mobile radio receiver according to Claim 20, characterized in that the analysis means and/or filtering means (11) are designed for carrying out the procedure according to Claims 1-19.

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FIG 1